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Xtrinsic Sensor Fusion Part 2: Alignment to Sensor Framework of Windows 8™, Android™ and Other Operating Systems

FTF-ENT-F0226

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Session Abstract

- Overview of the sensing framework for the latest OS specifications and the alignment and enablement provided by Xtrinsic Sensors

- This class focuses on inertial sensors used to *detect motion, and magnetic sensors used to detect orientation with respect to earth's magnetic field*

In Xtrinsic Sensor Fusion Part 1, we discussed

- Terms
  - Market Evolution
  - DOF vs. Number of Axes
  - Frames of Reference: NED vs. ENU
- Sensor Strengths and Weaknesses
- Basic Sensor Fusion
- Challenges
- Technical and Market Trends
- Product Timelines

Xtrinsic Sensor Fusion Part II Agenda

Movea Slides (Presented by Freescale)

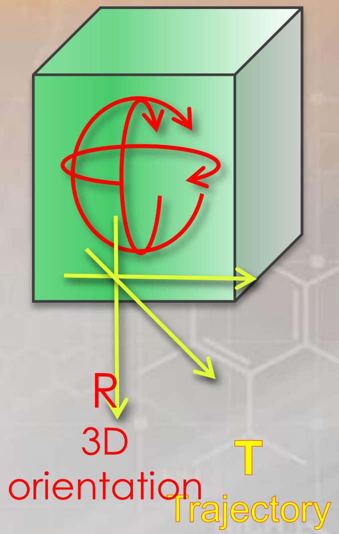
- Why is sensor fusion important?
- Sensor Hub Tradeoffs
- MotionCore Architecture
- Hub Environments

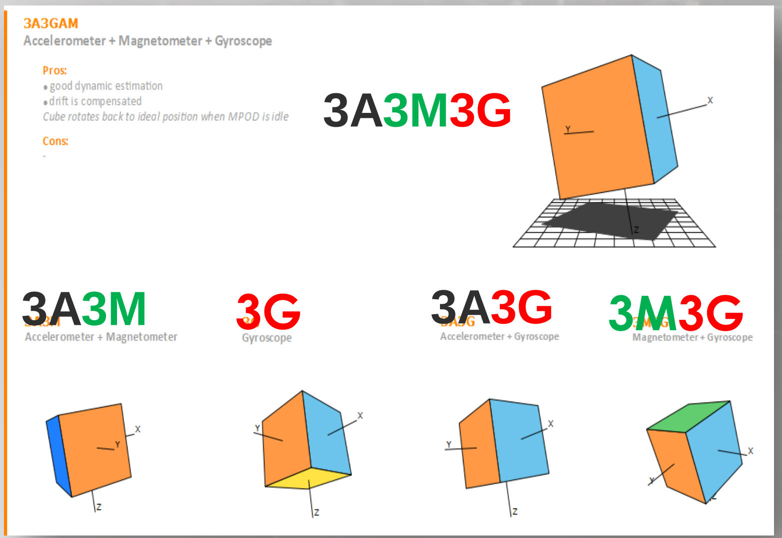
Freescale

- Baseline Sensor Fusion Block Diagram
- Snapshot: Android and Windows Today
- Xtrinisic Support for Android
- Xtrinsic Support for Windows 8
- Freescale Sensors Roadmap
- Xtrinsic Sensor Fusion Enablement
- Miscellaneous Sensor Topics (time permitting)
- Windows8 Sensor Demo (Technically challenged)

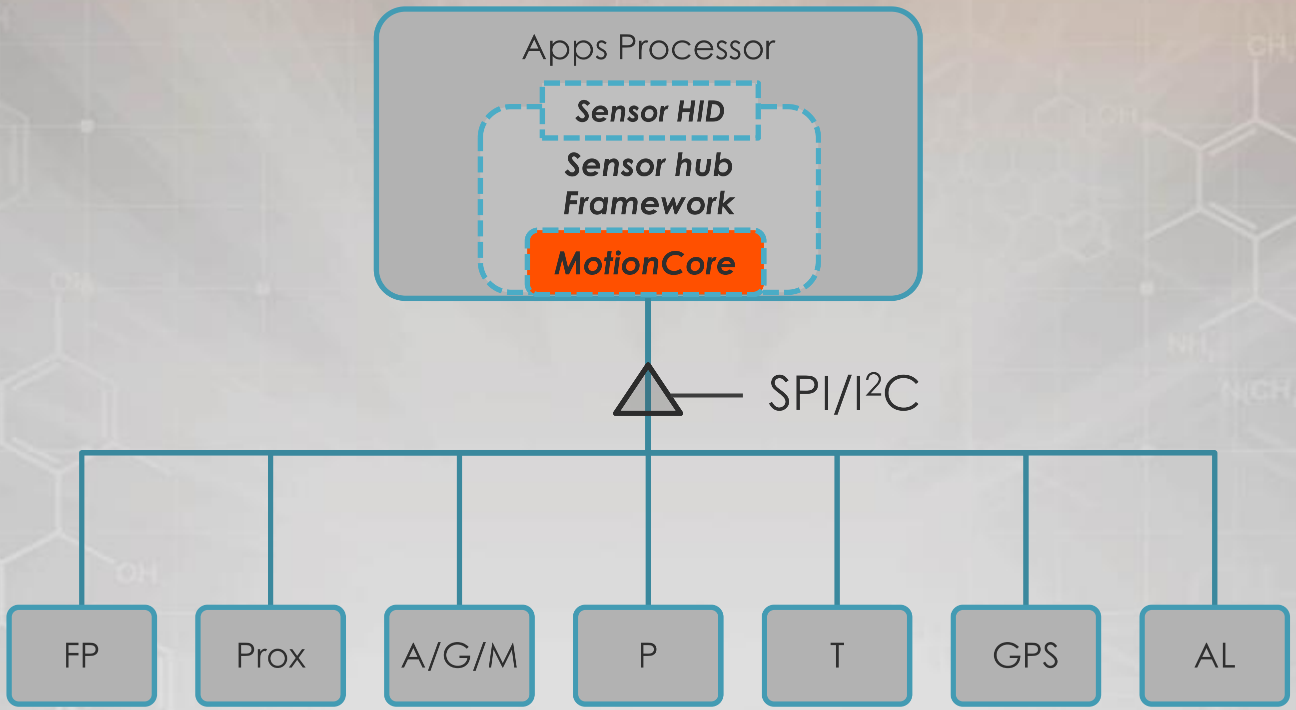
Why Data Fusion is Important

- **Weaknesses of individual sensors**
  - Accelerometers
    - Mix of gravity and acceleration
  - Magnetometers
    - hard iron, soft iron effects, spatially not constant (magnetic anomalies)
  - Gyroscopes
    - Drift with time, noise problems
- **Experience is needed to deliver the best cost/performance ratio optimized for the application**
- **Example: Swimming**
  - 3M can count laps. Additional sensors enable more advanced features like stroke detection.





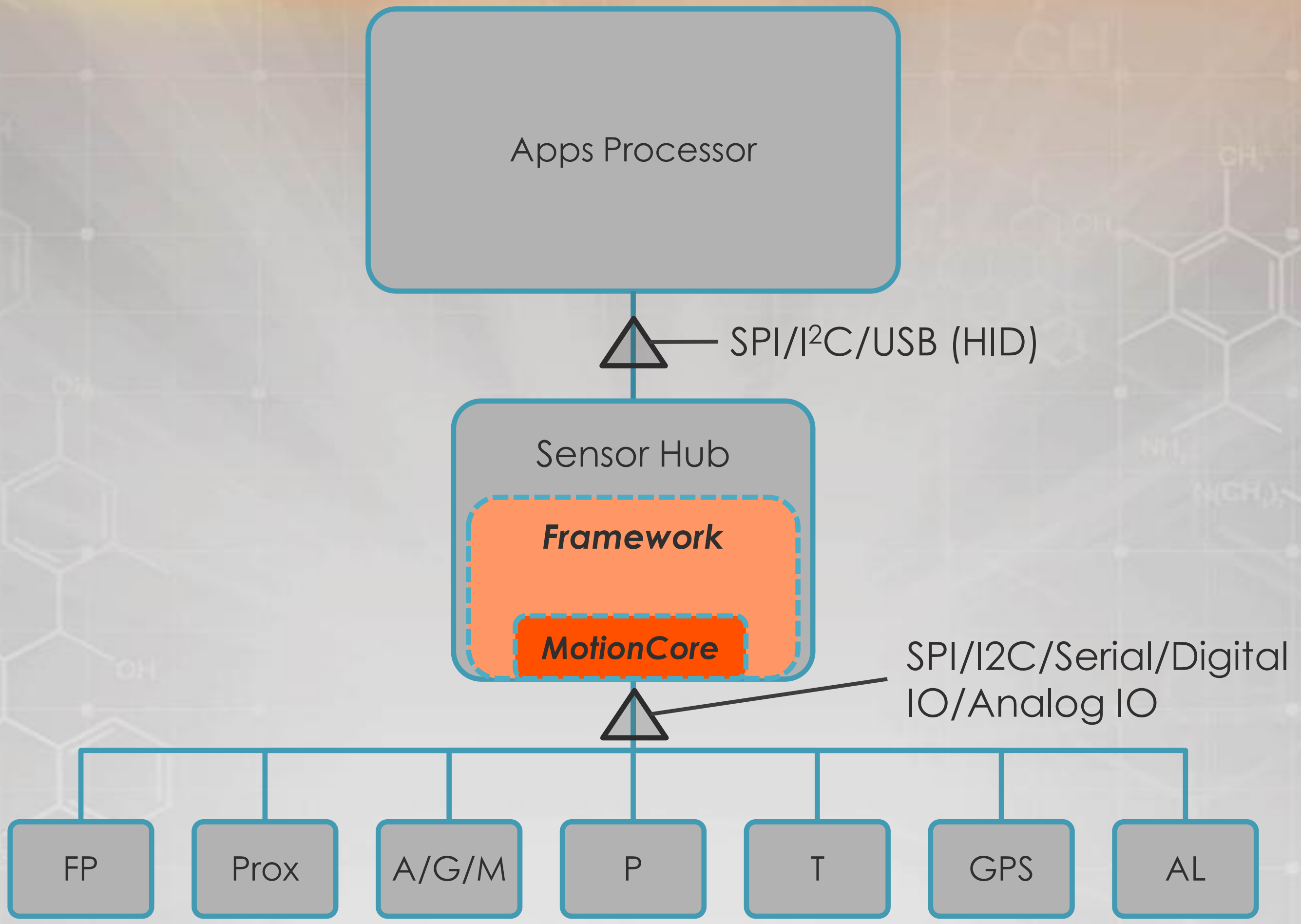
Sensor Hub Architecture



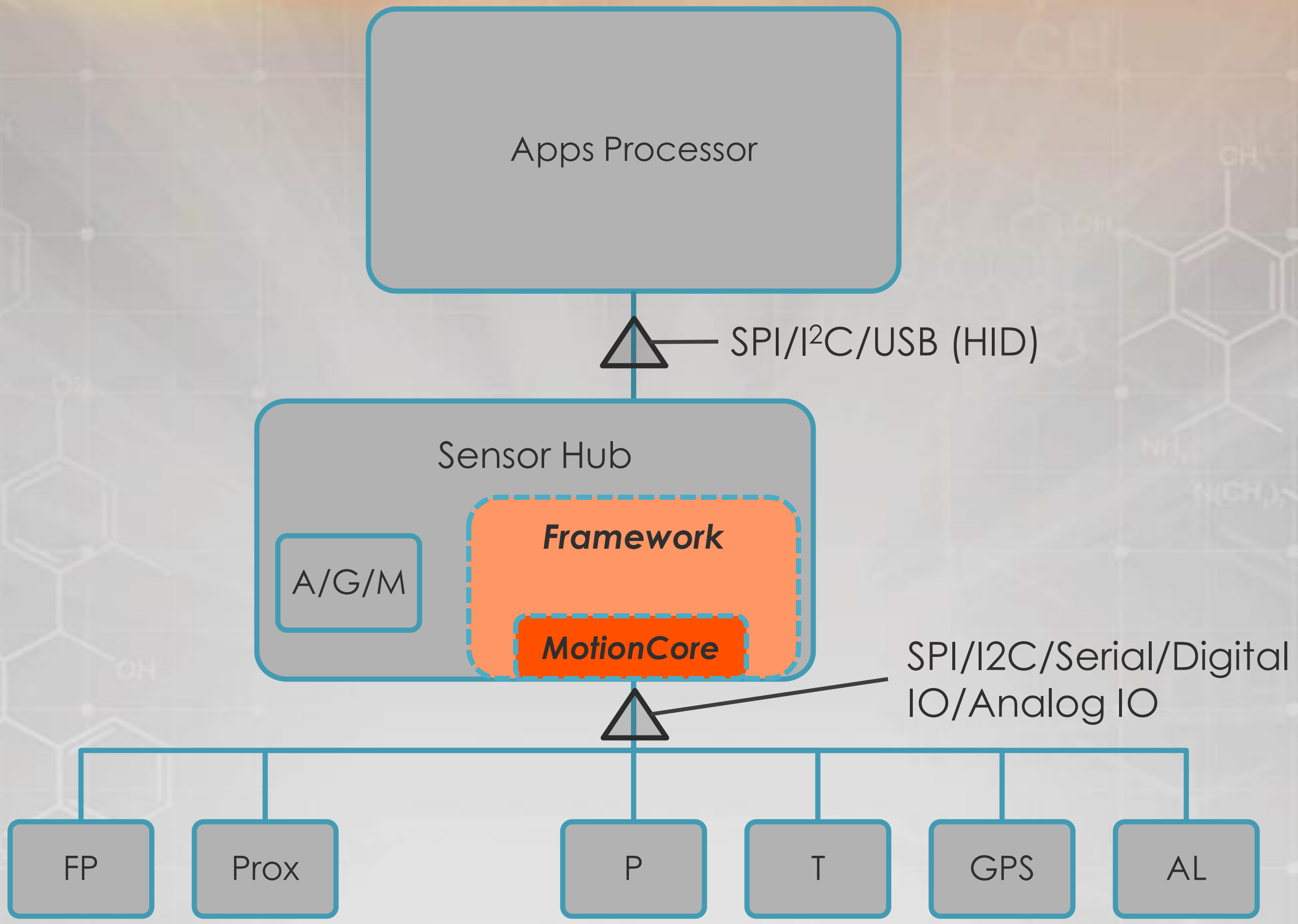
Sensor/Data Fusion

- A to A/M to A/M/G to A/M/G/P to A/M/G/P/GPS to A/M/G/GPS/camera
- Currently most mobile devices perform sensor fusion on the application processor
  - Power hungry
  - Computationally intensive
  - Not real time
  - Low bandwidth
- Future is "sensor hub"
  - Real time
  - High bandwidth
  - Low power

Sensor Hub Architecture



Sensor Hub Architecture



2 Levels of Sensor/Data Fusion

Merging low-cost sensors

and/or

and/or

and/or

Merging a priori information

Application scenario

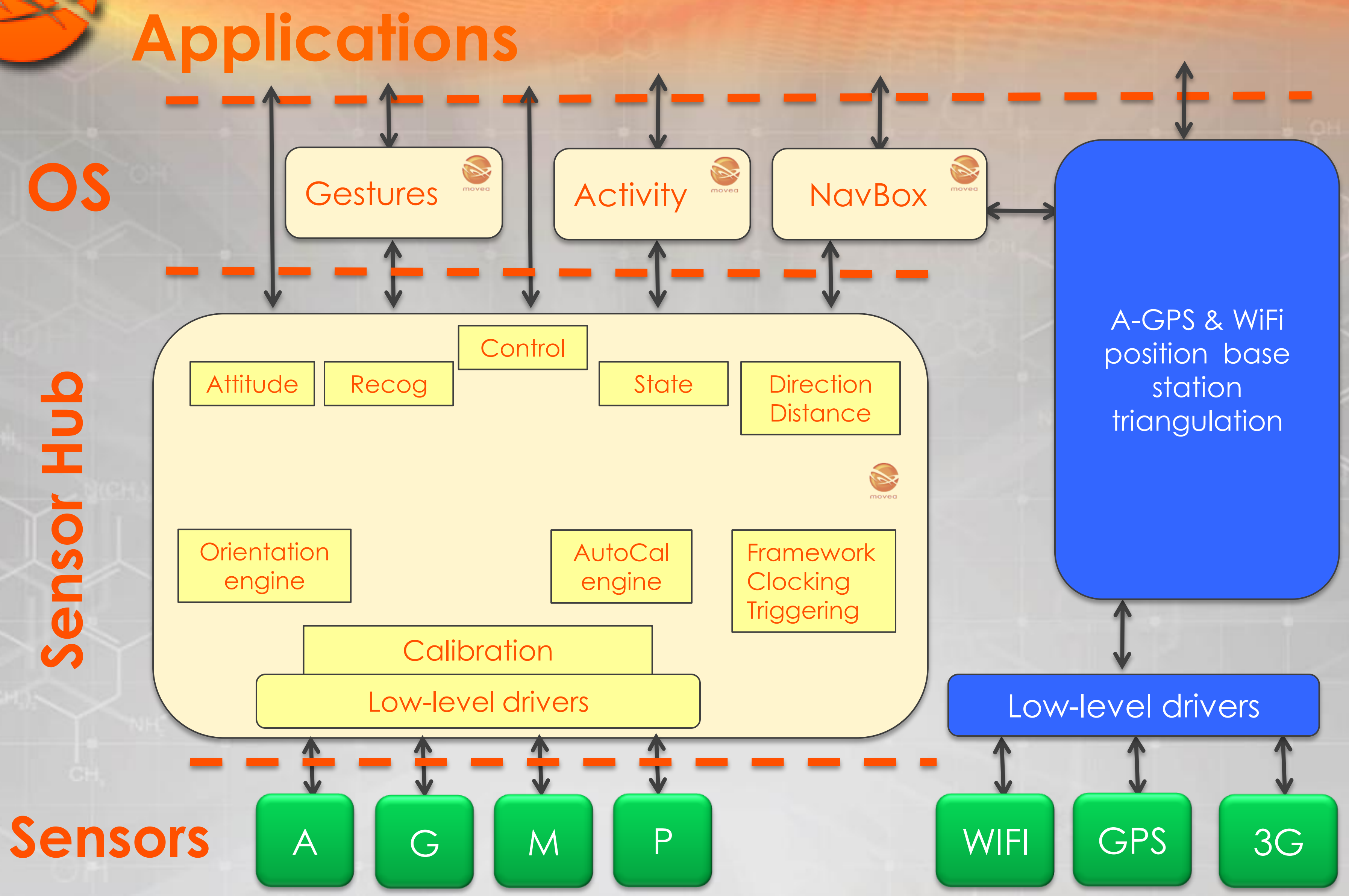
and/or

Gesture performed

and/or

Biomechanics knowledge

MotionCore Architecture



Hub Environments

- Generic Sensor Hub (A/G/M/P/GPS…)
  - Industrial applications
  - Fitness applications
  - Health care applications
- Win 8 Sensor Hub (A/G/M/P/ALS/TS/GPS/…)
  - Microsoft defined standard Win8 HID
  - Physical sensor hub
  - Real time constraints
  - Extended support
  - Power management
- Android Sensor Hub (A/G/M/P/ALS/TS/GPS/…)
  - Logical sensor hub
  - Community / Google defined
  - Power management

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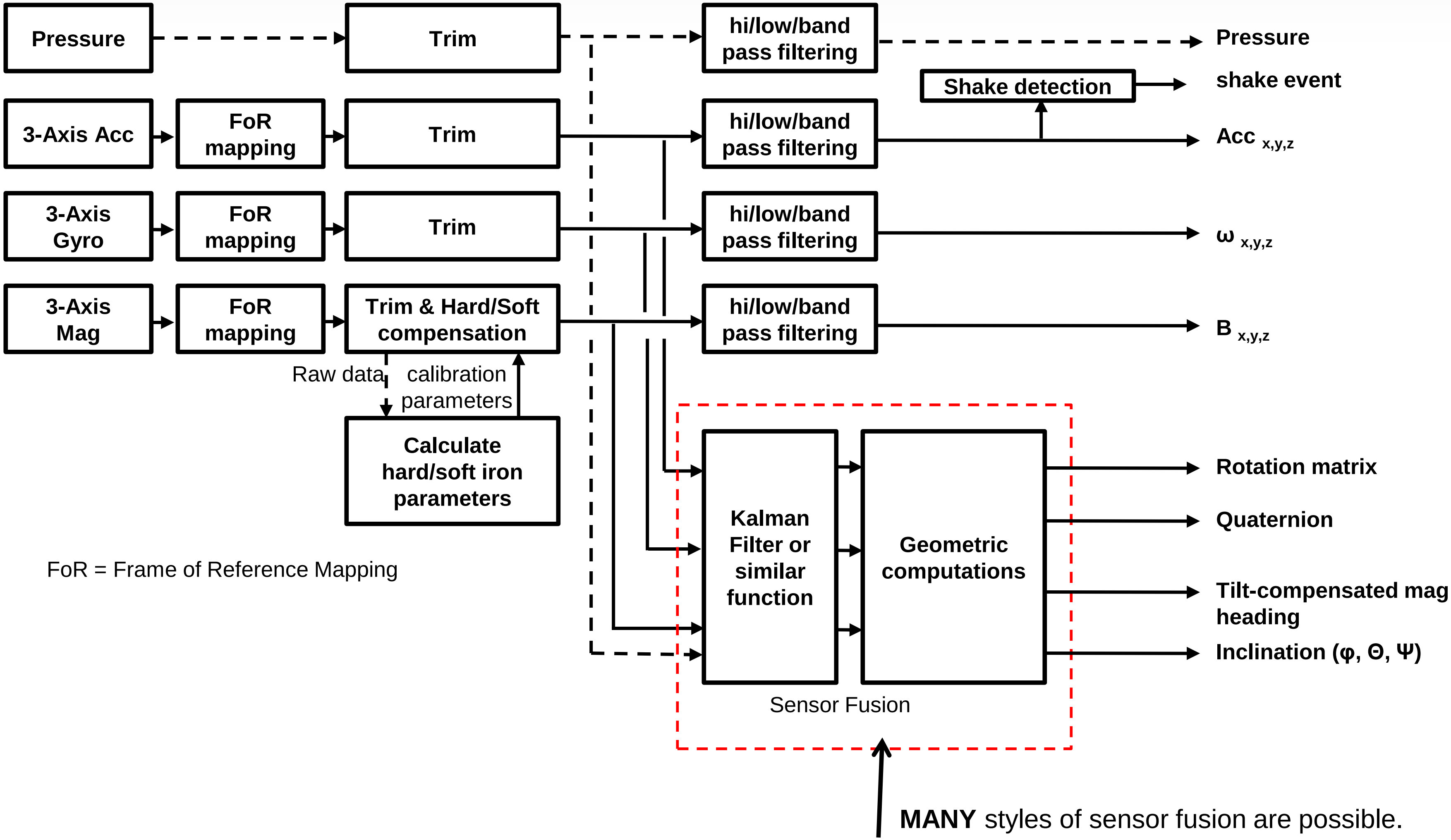
Baseline Sensor Fusion

Baseline Sensor Fusion



FoR = Frame of Reference Mapping

MANY styles of sensor fusion are possible.

Some Sensors are Physical, Some are "Virtual"

Sensor Type		Physical / Virtual
Acceleration	With gravity	Physical
	Without gravity	Virtual
Gravity		Virtual
Magnetic Field		Physical
Gyroscope		Physical
Orientation	Rotation Matrix	Virtual
	Quaternion	Virtual
	Euler Angles / Inclination	Virtual
	Compass heading	Virtual
Ambient Temperature		Physical
Light		Physical
Pressure		Physical
Proximity		Physical
Relative Humidity		Physical

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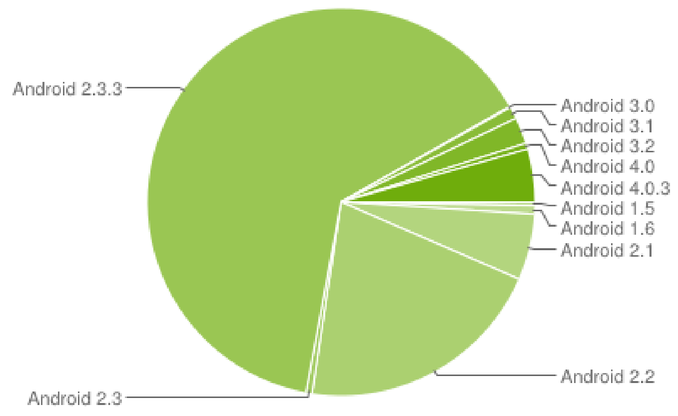
Snapshot: Android and Windows Today

Android Distributions as of 1 May 2012

Platform	Codename	API Level	Distribution
Android 1.5	Cupcake	3	0.3%
Android 1.6	Donut	4	0.7%
Android 2.1	Eclair	7	5.5%
Android 2.2	Froyo	8	20.9%
Android 2.3 - Android 2.3.2	Gingerbread	9	0.5%
Android 2.3.3 - Android 2.3.7		10	63.9%
Android 3.0	Honeycomb	11	0.1%
Android 3.1		12	1.0%
Android 3.2		13	2.2%
Android 4.0 - Android 4.0.2	Ice Cream Sandwich	14	0.5%
Android 4.0.3 - Android 4.0.4		15	4.4%

source: http://developer.android.com/resources/dashboard/platform-versions.html



OS Platform Statistics

2012	Win7	Vista	Win2003	WinXP	Linux	Mac	Mobile
Apr	51.3%	4.2%	0.6%	27.3%	4.9%	9.3%	1.5%
Mar	49.9%	4.3%	0.6%	28.9%	4.9%	8.9%	1.4%
Feb	48.7%	4.5%	0.7%	30.0%	5.0%	9.1%	1.3%
Jan	47.1%	4.7%	0.7%	31.4%	4.9%	9.0%	1.3%

source: http://www.w3schools.com/browsers/browsers_os.asp

Physical Sensor Requirements

Feature	Android 4.0.x	Android 2.3.3	Android 2.2 / 2.1 / 1.6	Win 8 Slate / Convertible Laptop
3-axis accelerometer	• **SHOULD** have • Min sps = 50 sps • Min +/- 2g range • Min resolution = 8 bits • Max std dev = $0.05 m/s^2$	• Ditto 4.0.x	• **MUST** include • >= 50 sps	• **REQUIRED** • Range = +/- 2 g min • Range = +/- 8 g optimal • 100 sps required • 200 sps optimal • 350 μg / rtHz @10Hz • 0.5% non-linearity
3-axis magnetometer	• **SHOULD** have • Min sps = 10 sps • Range > earth mag field • Min resolution = 8 bits • Max std dev = 0.5 μT	• Ditto 4.0.x	• **MUST** include a 3-axis Compass • >= 10 sps	• **REQUIRED** for sensor fusion, not directly accessible • +/- 1000 μT • 0.5 μT / rtHz @ 8 Hz • 0.3 μT / LSB desired • Min sps = 8
GPS	• **SHOULD** have • "assisted GPS" suggested	• Ditto 4.0.X	• Ditto 4.0.X	**Supported**
Gyroscope	• **SHOULD** have (but only if 3-axis acc is present) • Temp compensation required • Min range = 5.5 π rad/sec • Min sps = 100 • Min resolution = 12 bits • Variance <= 10^{-7} $rad^2/sec^2/Hz$ • Timestamp required	• Range >= 5.5π radians/sec • >= 100 sps • >= 8 bits	• No mention	• **REQUIRED** • Range = +/- 720 dps min • Range = +/- 2000 dps optimal • 0.2% non-linearity • Noise: 0.05 dps-rms@100Hz • Sensitivity scale factor tolerance = +/- 3% at 25C • Zero rate offset = +/- 20 dps • Recommended sps > 100

Physical Sensor Requirements

Feature	4.0.x / 2.3.3	2.2 / 2.1 / 1.6	Windows 8
barometer	MAY have >= 5 sps “MUST have adequate precision to enable estimating altitude”	No mention	**Supported**
thermometer	MAY but SHOULD NOT MUST measure CPU temp only. This sensor type is deprecated in Android 2.3 and 4.0 APIs.	**Supported**	**Supported**
photometer (ambient light sensor)	MAY include	No mention	Supported via ACPI
proximity sensor	MAY include 1 bit accuracy or greater	No mention	**Supported**

Notes:

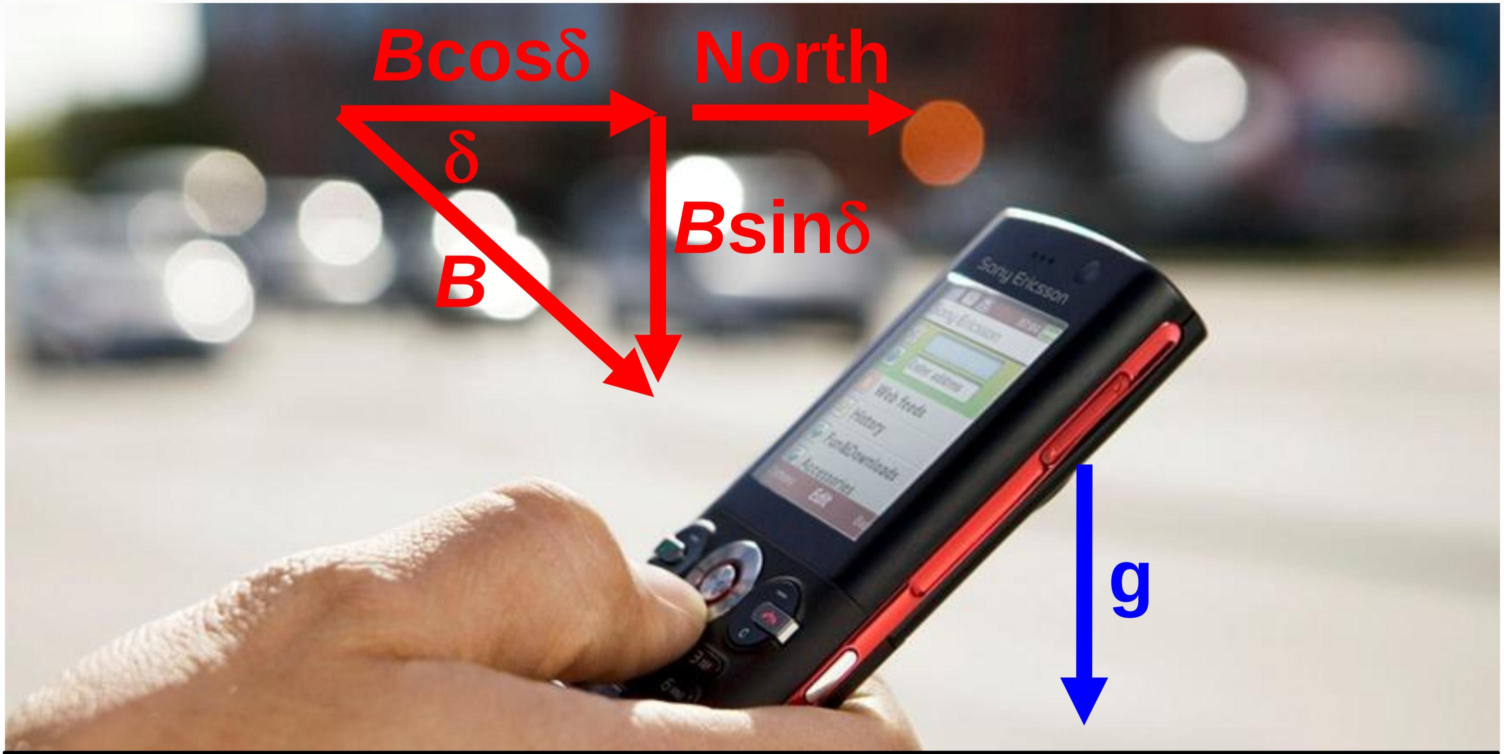
1. Tables are based on information in Android Compatibility Definitions for these releases
2. Excepting ambient light sensor, Windows 8 utilizes HID over USB or simple peripheral bus (SPI, I^2C for sensor support)
3. Windows 8 HID definitions support other sensor types which are not shown (current, power, voltage, switches)

Sensor Types vs. Release Level

Android Sensor	Android 4.0 (API Level 14)	Android 2.3 (API Level 9)	Android 2.2 (API Level 8)	Android 1.5 (API Level 3)	Windows 8 equivalent
TYPE_ACCELEROMETER	Yes	Yes	Yes	Yes	Yes
TYPE_AMBIENT_TEMPERATURE	Yes	n/a	n/a	n/a	Yes
TYPE_GRAVITY	Yes	Yes	n/a	n/a	n/a
TYPE_GYROSCOPE	Yes	Yes	n/a[1]	n/a[1]	Yes
TYPE_LIGHT	Yes	Yes	Yes	Yes	Yes
TYPE_LINEAR_ACCELERATION	Yes	Yes	n/a	n/a	Yes
TYPE_MAGNETIC_FIELD	Yes	Yes	Yes	Yes	Yes
TYPE_ORIENTATION	Yes[2]	Yes[2]	Yes[2]	Yes	Yes
TYPE_PRESSURE	Yes	Yes	n/a[1]	n/a[1]	Yes
TYPE_PROXIMITY	Yes	Yes	Yes	Yes	Yes
TYPE_RELATIVE_HUMIDITY	Yes	n/a	n/a	n/a	Yes
TYPE_ROTATION_VECTOR	Yes	Yes	n/a	n/a	Yes
TYPE_TEMPERATURE	Yes[2]	Yes	Yes	Yes	Not standard

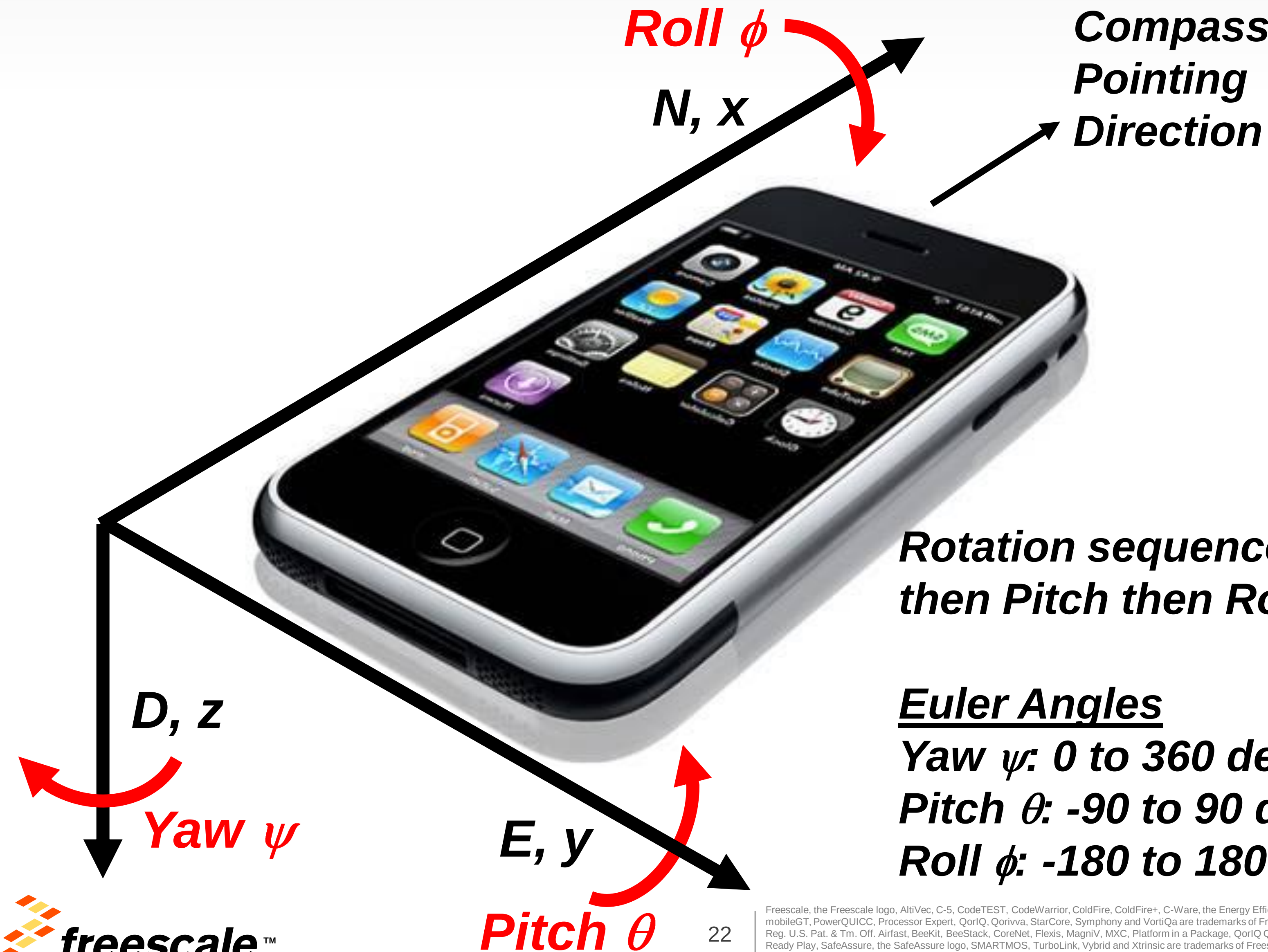
1. This sensor type was added in Android 1.5 (API Level 3), but it was not available for use until Android 2.3 (API Level 9)
2. The sensor is available, but it has been deprecated.
   – source: http://developer.android.com/guide/topics/sensors/sensors_overview.html

Geomagnetic and Gravitational Fields



B is the geomagnetic field (magnitude 40 to 60uT worldwide) whose horizontal component points to the north geomagnetic pole.
δ is the inclination angle: positive (points down) in the northern hemisphere and negative (points up) in the southern hemisphere.
We use these two vectors to determine the orientation of the phone.

iPhone / Aerospace / NED Coordinate System and Euler Angles



Rotation sequence Yaw then Pitch then Roll

<u>Euler Angles</u>

Yaw ψ: 0 to 360 deg

Pitch θ: -90 to 90 deg

Roll ϕ: -180 to 180 deg

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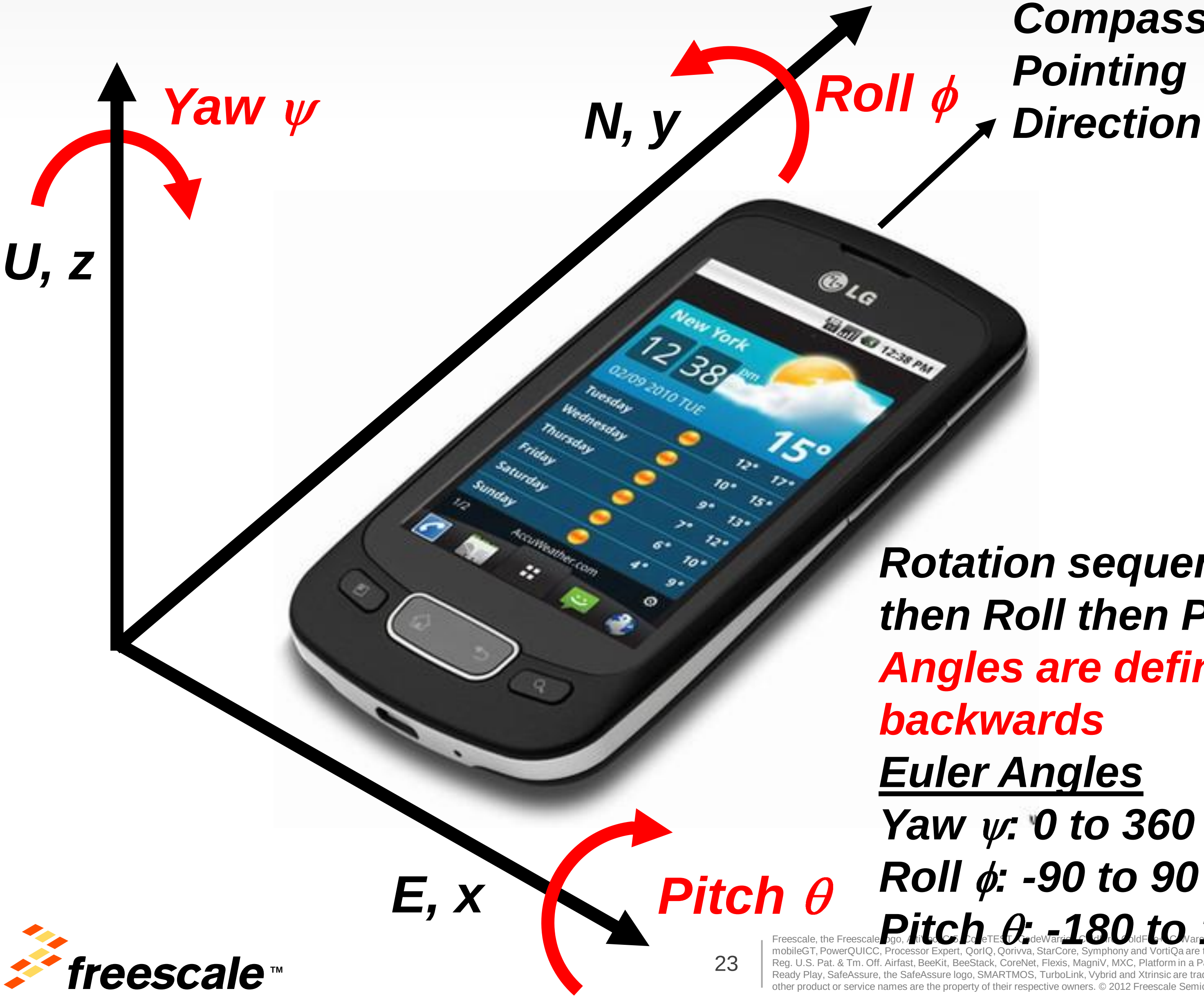
Android Coordinate System and Euler Angles



Rotation sequence Yaw then Roll then Pitch

Angles are defined backwards

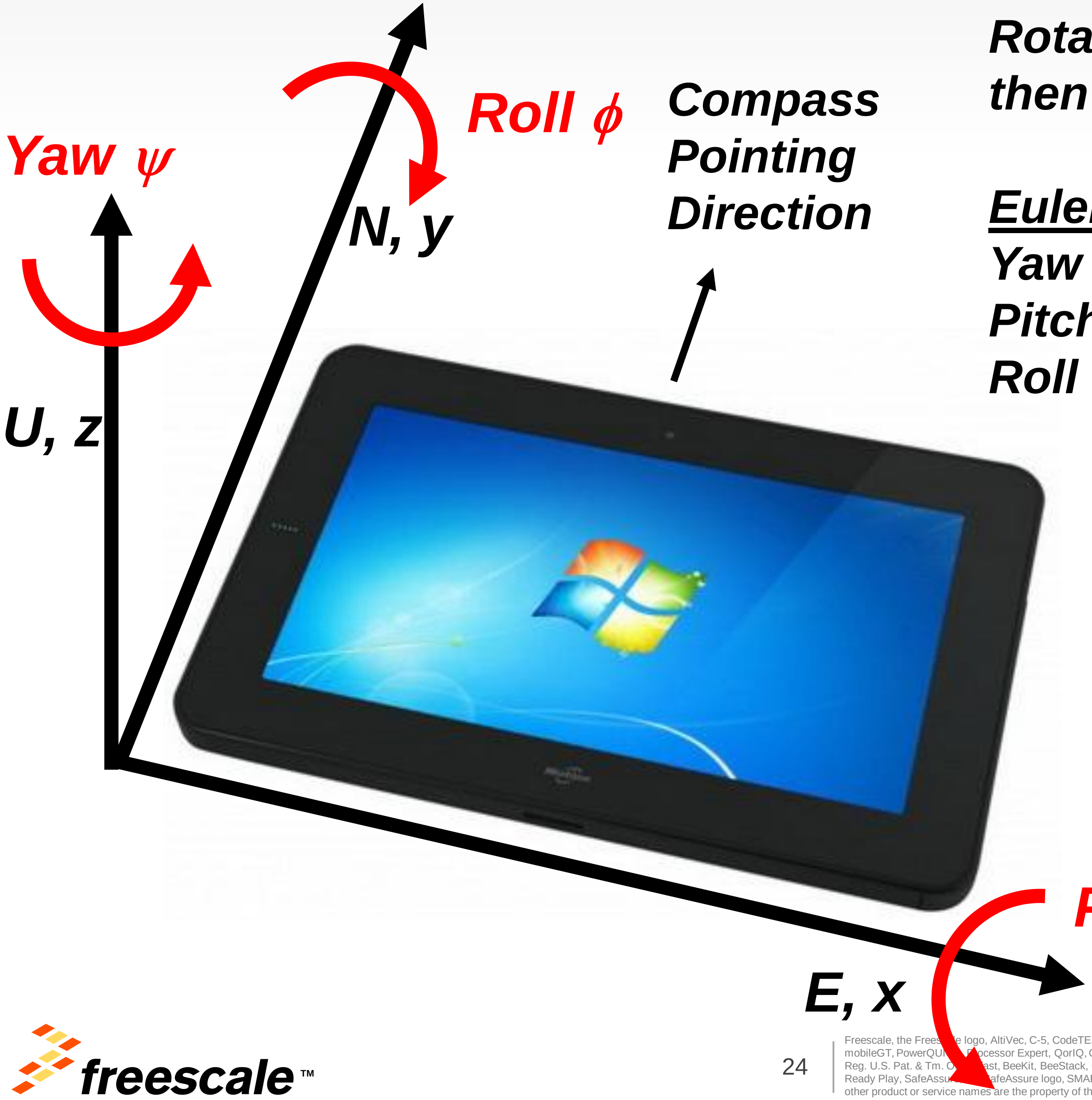
Euler Angles

Yaw ψ: 0 to 360 deg

Roll ϕ: -90 to 90 deg

Pitch θ: -180 to 180 deg

Windows 8 Coordinate System and Euler Angles



Rotation sequence Yaw then Pitch then Roll

<u>Euler Angles</u>

Yaw ψ: 0 to 360 deg
Pitch θ: -180 to 180 deg
Roll ϕ: -90 to 90 deg

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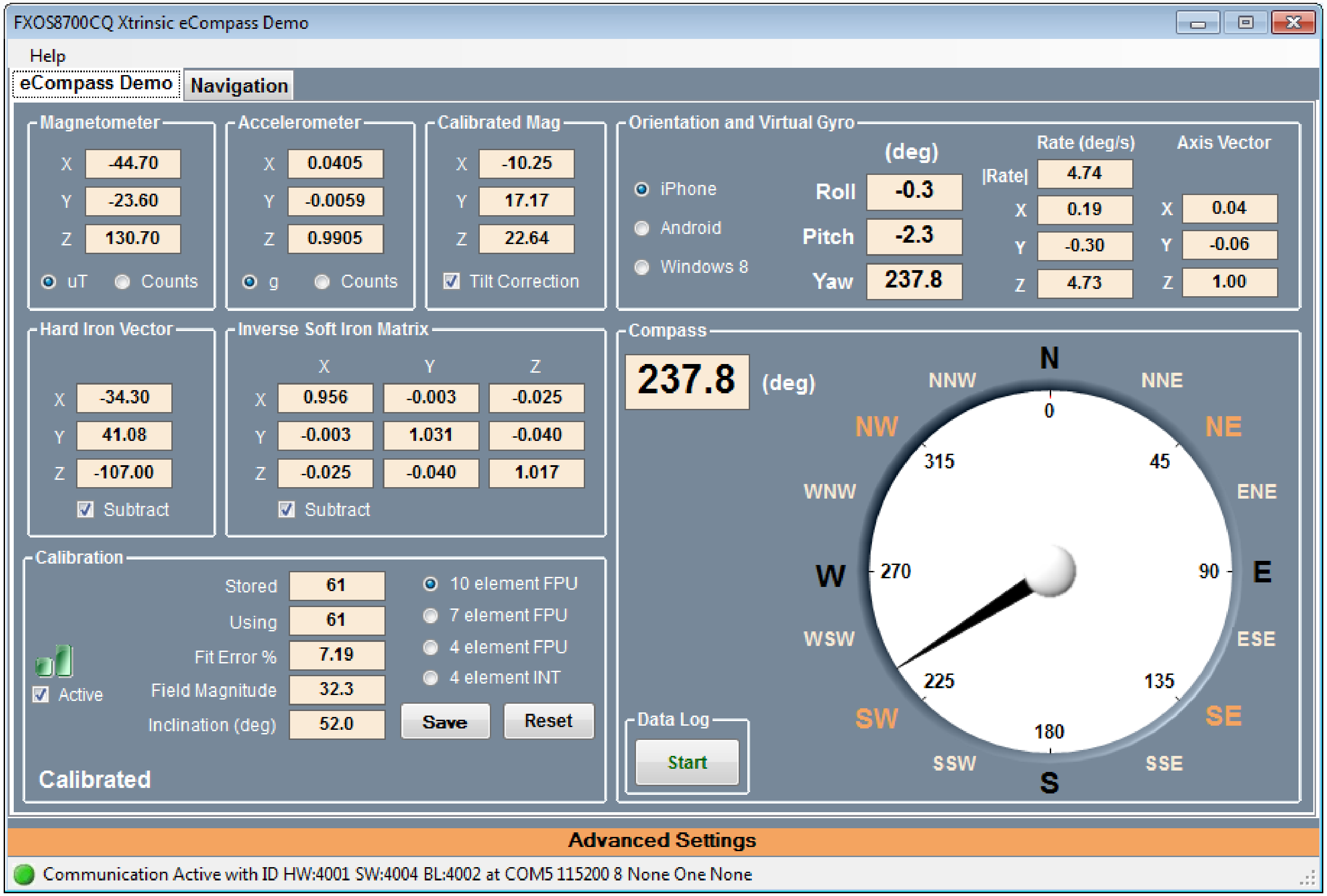
Differences in OS Frames of Reference

	NED Aerospace iPhone	Android	Windows 8
Accelerometer output	Gravity-Acceleration	Acceleration-Gravity	Gravity-Acceleration
Axes alignment	NED	ENU	ENU
Angle rotation order	Yaw then pitch then roll	Yaw then roll then pitch	Yaw then pitch then roll
Axis rotation order	z then y then x	z then y then x	z then x then y
Rotation matrix	$R_x(\Phi)\ R_y(\theta)\ R_z(\psi)$	$R_x(\theta)\ R_y(\Phi)\ R_z(\psi)$	$R_y(\Phi)\ R_x(\theta)\ R_z(\psi)$
Equivalent matrix	$R_x(\Phi + \pi)\ R_y(\pi - \theta)\ R_z(\psi + \pi)$	$R_x(\theta+\pi)\ R_y(\pi - \Phi)\ R_z(\psi+\pi)$	$R_y(\Phi - \pi)\ R_x(\pi - \theta)\ R_z(\psi + \pi)$
Gimbal lock	Roll instability (x axis) at +/- 90 deg pitch (y axis)	Pitch instability (x axis) at +/- 90 deg roll (y axis)	Roll instability (y axis) at +/- 90 deg pitch (x axis)
Gimbal lock fix	Mix x accel into y accel	Mix x accel into y accel	Mix y accel into x accel
Accel units	g	m/s2	g
Acceleration when flat	z=+1g	z=+9.81ms/2	z=-1g
Mag units	μT fractional	μT integer	μT fractional
Roll range	Clockwise -180 to 180 deg	Anti-clockwise -90 to 90 deg	Clockwise -90 to 90 deg
Pitch range	-90 to 90 deg	-180 to 180 deg	-180 to 180 deg
Yaw range	0 to 360	0 to 360	0 to 360
Compass heading	Yaw	Yaw	Minus Yaw

Differences in OS Frames of Reference

	NED Aerospace iPhone	Android	Windows 8
Behaviour during +/- 180 deg roll rotation	Roll is continuous in range -180 to 180 deg. No change in yaw or compass angle.	Xoom: Roll is continuous increasing to 90 deg and then decreasing or decreasing to -90 deg and then increasing. Pitch and Yaw have 180 deg discontinuities at +/- 90 deg roll.	180 deg jump in roll, pitch, yaw and compass as the roll angle passes 90 deg and -90 deg.
Behaviour during +/- 180 deg pitch rotation	Pitch is continuous increasing to 90 deg and then decreasing or decreasing to -90 and then increasing. Roll and Yaw have 180 deg discontinuity at +/- 90 degrees pitch.	Xoom: Smooth changes in pitch. No change in roll, yaw or compass.	Smooth changes in pitch. No change in roll, yaw or compass.
Gyroscope	Clockwise deg/sec Equals NED roll, pitch, yaw rotation rates except for pitch angle when inverted.	Clockwise radians/sec Negative of Android roll, pitch, yaw rates	Clockwise deg/sec Equals Windows 8 roll, pitch, yaw rotation rates

Variations in Roll & Pitch Can Be Explored via the FXOS8700CQ Xtrinsic eCompass Demo



Compatibility Testing

Android

- Compatibility is checked via the Android Compatibility Test Suite (CTS) available at:http://source.android.com/compatibility/downloads.html.
- See http://source.android.com/compatibility/ for more details

Windows 8

- Microsoft supports a graphical sensor diagnostic tool for verification of sensor data and properties.
- Information on Windows 8 Hardware Certification Requirements can be found at: http://msdn.microsoft.com/en-us/library/windows/hardware/hh748200.aspx
- Additional information is available under NDA from Microsoft

What’s Built-In?

Feature	Android	Windows 8
Adaptive Brightness		X
Portrait landscape	X	X
Location Services	X	X
Sensor Fusion	‘light fusion’ included in Android	Sensor fusion generally provided by sensor vendor or OEM

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Xtrinisic Support for Android

Freescale Android Drivers

Sensor	Linux® Kernel	Android 2.2 Froyo	Android 2.3 GingerBread	Android 4.0 Ice Cream Sandwich
MMA8451Q accelerometer	•	•	•	•
MMA8452Q accelerometer	•	•	•	•
MMA8453Q accelerometer	•	•	•	•
MMA8450Q accelerometer	•			
MMA7660FC accelerometer	•	•	•	•
MMA7455L accelerometer	•			
MAG3110 magnetometer	•	•	•	•
MPL3115A2 pressure Sensor	•	•	•	•
MPR121 touch sensor	•	•	•	•
MPR031 touch sensor	•	•	•	•

Freescale Software Driver Packages

Driver Package	OS	Description
Xtrinsic MMA845xQ accelerometer Linux® kernel driver	Linux	Xtrinsic MMA8451Q, MMA8452Q, MMA8453Q accelerometer Linux 2.6.35 kernel driver source code supporting sensor's complete embedded feature sets
Xtrinsic MMA7660FC accelerometer Linux kernel driver	Linux	Xtrinsic MMA7660FC accelerometer Linux 2.6.35 kernel driver source code supporting sensor's complete embedded feature sets
Xtrinsic MMA8450Q accelerometer Linux kernel driver	Linux	Xtrinsic MMA8450Q accelerometer Linux 2.6.35 kernel driver source code supporting sensor's complete embedded feature sets
Xtrinsic MAG3110 magnetometer Linux kernel driver	Linux	Xtrinsic MAG3110 magnetometer Linux 2.6.35 kernel driver source code supporting sensor's complete embedded feature sets
Xtrinsic MPL3115A2 Linux kernel driver	Linux	Xtrinsic MPL3115A2 Linux 2.6.35 kernel driver source code supporting basic features
Freescale sensor driver package for Android™ 2.2	Android	Includes Linux kernel drivers, Android HAL for accelerometers, magnetometers, orientation sensors and the barometer. Also includes the source code for the MAG3110 magnetometer hard iron and soft iron calibration (eCompass lite version) Devices supported: MMA8451Q, MMA8452Q, MMA8453Q, MAG3110, MPL3115A2 Platform: i.MX5x
Freescale sensor driver package for Android 2.3	Android	Includes Linux kernel drivers, Android HAL for accelerometers, magnetometers, orientation sensors and barometer. Also includes the source code for MAG3110 magnetometer hard iron and soft iron calibration (eCompass lite version) Devices supported: MMA8451Q, MMA8452Q, MMA8453Q, MMA7660FC, MAG3110, MPL3115A2 Platform: i.MX5x
Freescale sensor driver package for Android 4.0	Android	Includes Linux kernel drivers, Android HAL for accelerometers, magnetometers, orientation sensors and barometer. Also includes the source code for the MAG3110 magnetic sensor hard iron and soft iron calibration (eCompass lite version) Devices supported: MMA8451Q, MMA8452Q, MMA8453Q, MMA7660FC, MAG3110 Platform: i.MX5x
MPR03x Android/Linux driver	Android	MPR03x touch sensor driver source code for Android 4.0/Linux 2.6.35
MPR121 Android/Linux driver	Android	MPR121 touch sensor driver source code for Android 4.0/Linux 2.6.35

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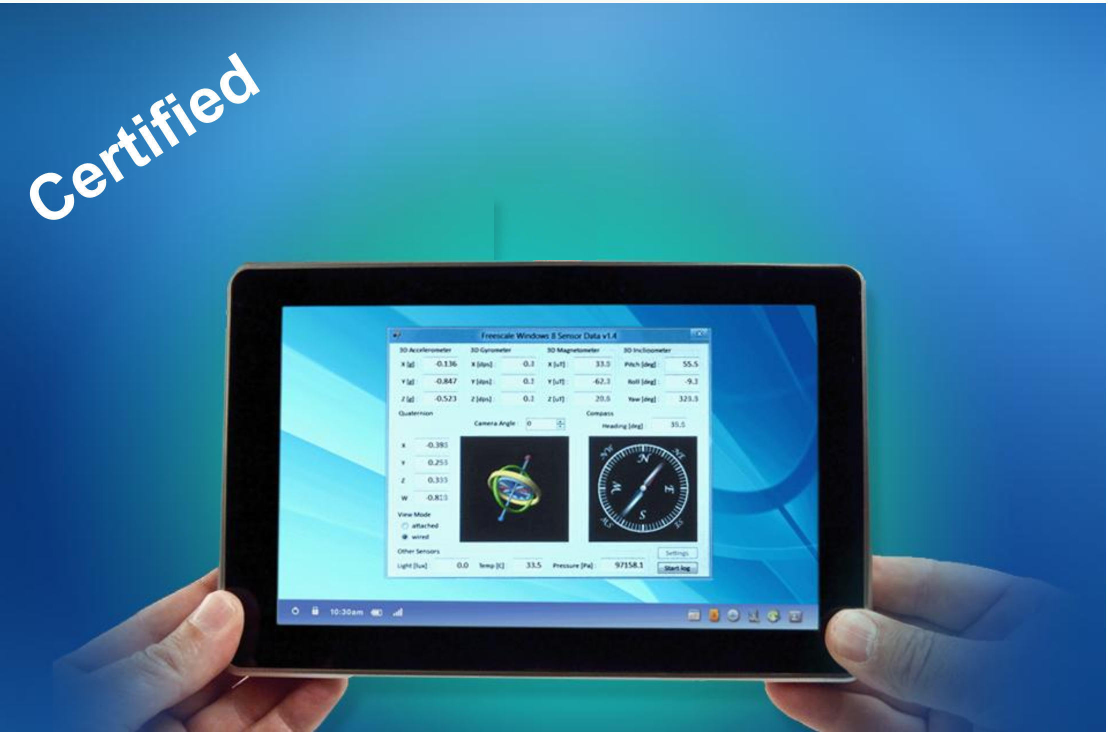
Xtrinsic Support for Windows 8

Windows 8 Freescale 12-Axis Xtrinsic Sensor Platform

Xtrinsic sensor fusion in tablets, slates, convertible/non-convertible laptops and other portable devices



escale Certified for Windows 8 Requirements

- **Microsoft certification was granted August 2012**
- **Windows 8 operating system released on 26 October**
- **Windows Hardware Certification Kit (WHCK) entailed the following:**
  - Windows 8 sensor test criteria for passing
  - Tests ensure hardware/software compatibility

- **Outcome:**
  - Windows 8 device manager compatibility
  - Freescale added to Microsoft's approved vendor database

Learn more at https://sysdev.microsoft.com/en-US/Hardware/lpl

Windows 8 Sensor Platform

First phase design uses USB connectivity

Hardware includes:

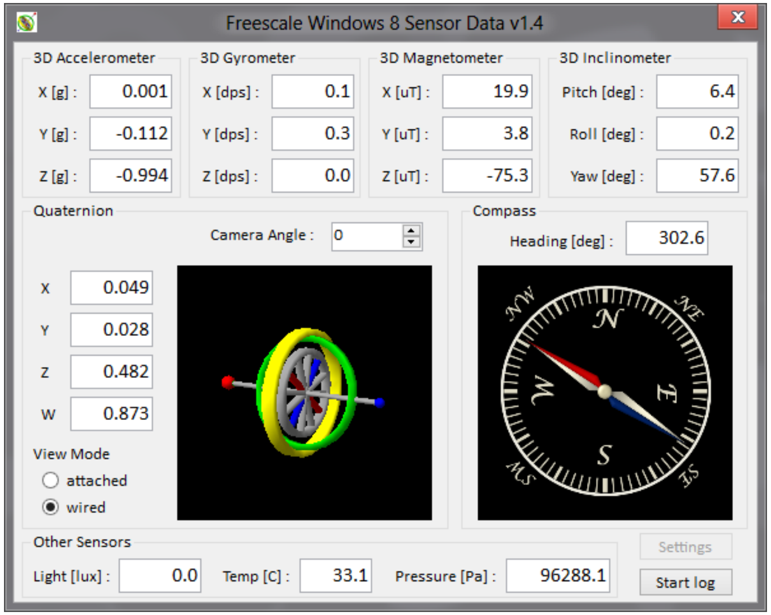
- Accelerometer
- Magnetometer
- Gyro
- Altitude
- Ambient light sensor

Sensor Fusion provides:

- Gyro trim
- Compass heading
- Orientation / rotation

In development:

- Magnetic anomaly handling
- Power reduction
- I2C interface



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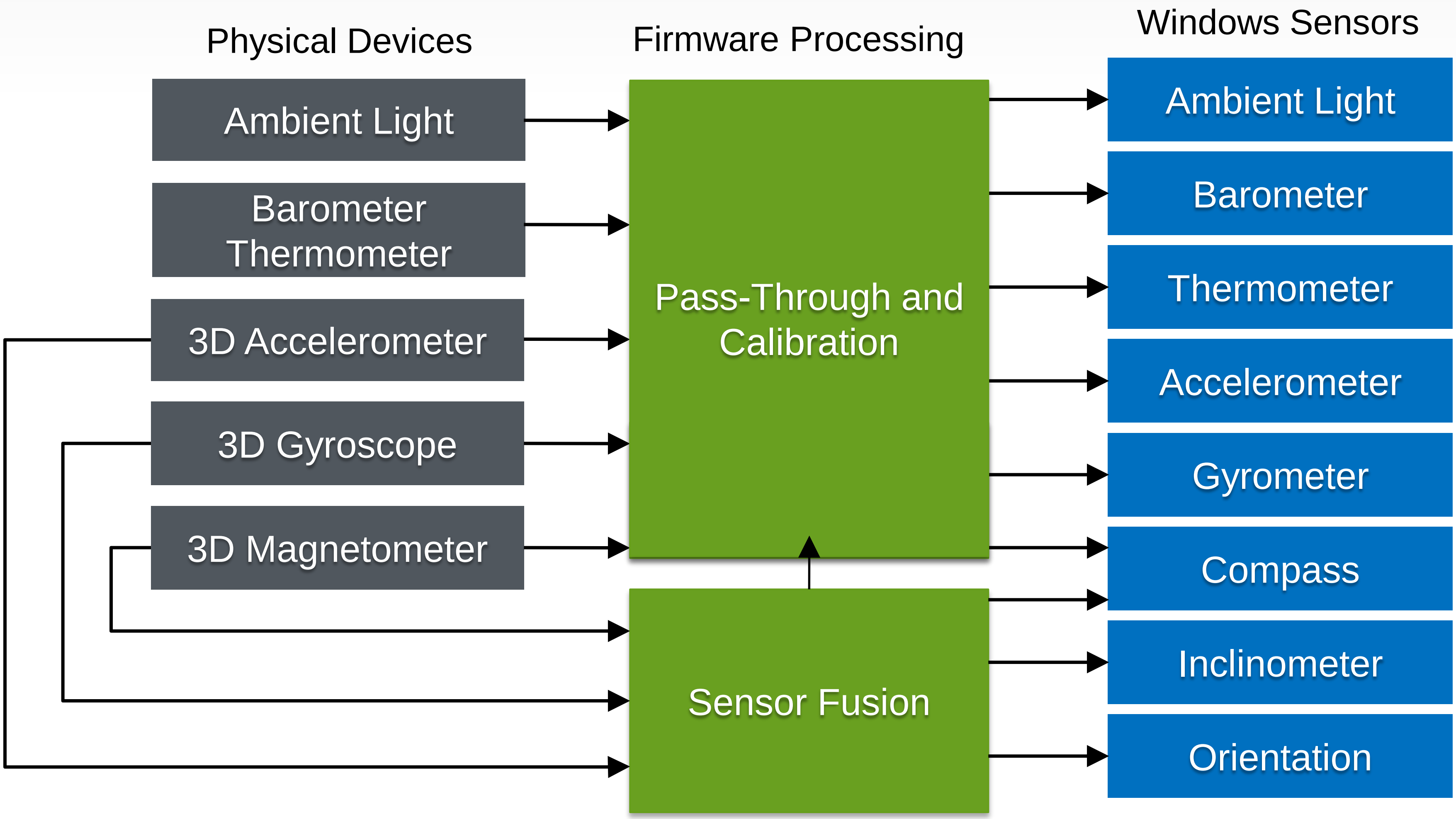
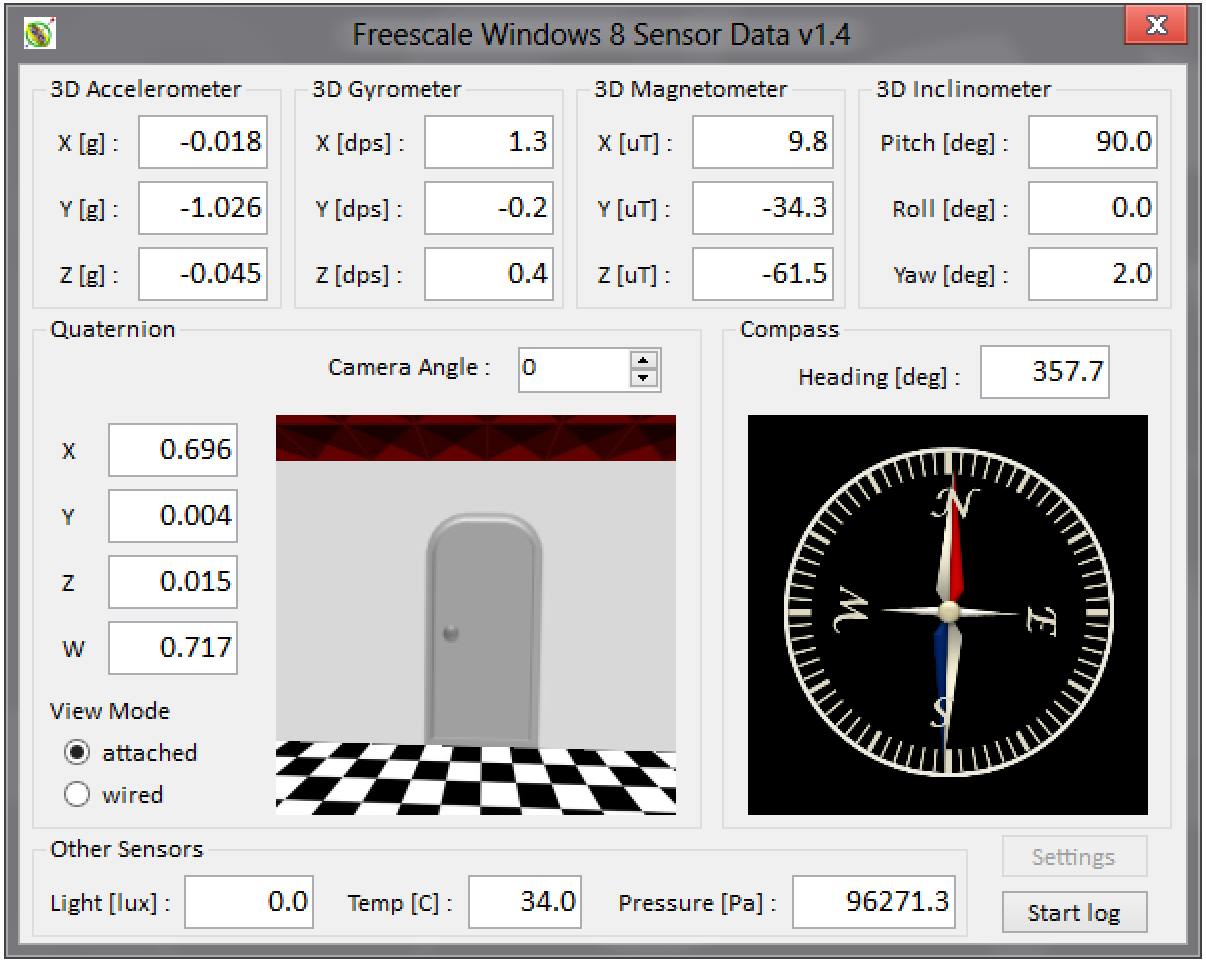
Windows 8 Xtrinsic Sensor Data Flow



Alternate View of Freescale Windows 8 Sensor Data Tool



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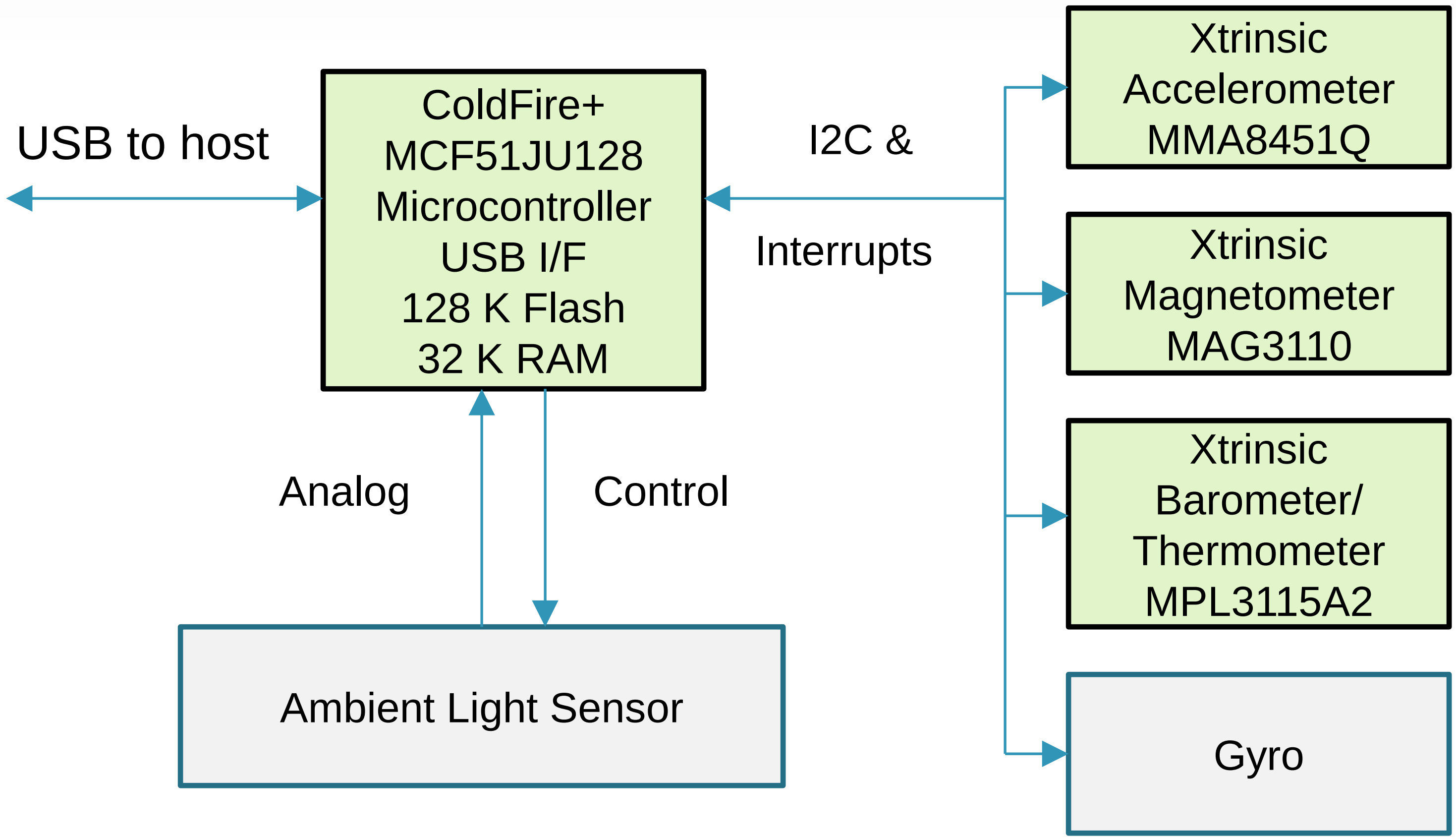
Windows 8 Xtrinsic Sensor Platform Block Diagram



Freescale Technology

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Freescale Sensors

Marc Holbein
Product Definer
Analog and Sensors

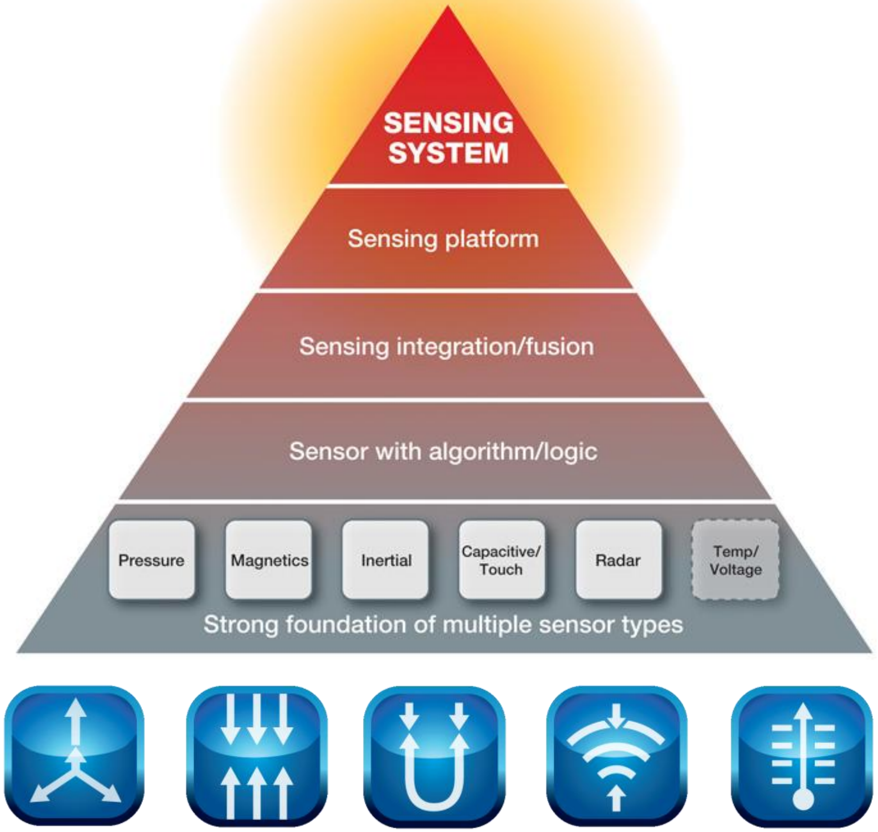
November7, 2012

Freescale's New Era of Xtrinsic Sensing

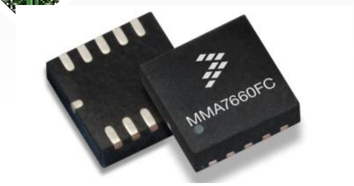
Intelligent Contextual Sensing – *more than translating a signal*

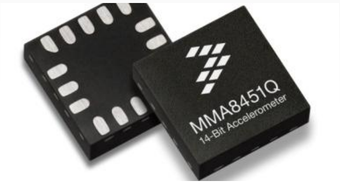
Xtrinsic Sensing Solutions

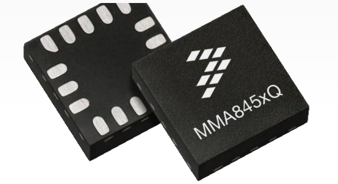
- **Increasing levels of intelligence**
  - Decision making
  - Software enablement
  - Programmability
  - Applications
  - Third-party software
- **Increasing levels of integration**
  - Sensor fusion
  - Connectivity
  - Power management
  - Logic
  - Actuation

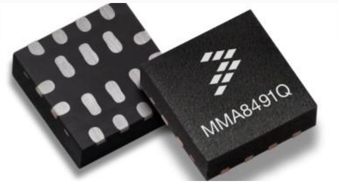


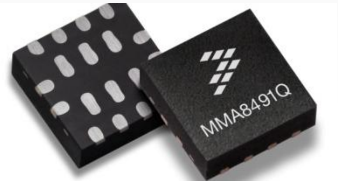
C&I Accelerometer Family











MMA865x

- Digital Output
- Cost Efficient
  - 1mg/count sensitivity
- High Performance
- Rich Features
  - P/L detection
  - High Pass Filter
  - Transient Detect

MMA845x

- Digital Output
- Extreme Performance
  - .25mg/count sensitivity
- Extended Features
  - FIFO
  - Configurable P/L trip angles
  - High Pass Filter
  - Transient Detect

MMA8450

- Digital Output
- Low Voltage
  - 1.71-1.89V

MMA8491

- Digital Output
- Extreme Low Power
  - 0.35uA/Hz
- Cost Efficient
  - 1mg/count sensitivity
- Industrial Package

MMA837x

- Analog Output
- High Bandwidth
  - 4.9kHz
- Low Voltage
  - 1.71-3.6V
- Industrial Package
- Extended Temp Range: 105C

Consumer (MMA865x, MMA845x, MMA8450) | Industrial (MMA8491, MMA837x)

Xtrinsic Low-G Sensors (Veyron, Newton)

3-axis High-Performance Digital Accelerometers

Differentiating Points

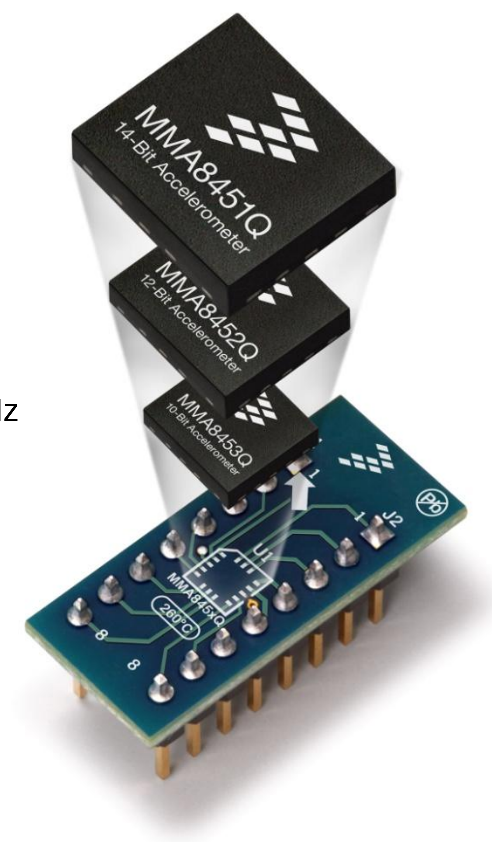
- Output Noise (<150ug/rHz)
- Offset and Sensitivity Accuracy
- Resolution up to 0.25mg/count

Product Features

- 1.95V to 3.6V supply voltage
- ±2g/±4g/±8g dynamically selectable
- Output data rate (ODR) from 800Hz to 1.563Hz
- I²C/SPI digital output interface w/interrupts
- Embedded orientation (Portrait/Landscape)
- Embedded High Pass Filter
- Embedded 32 sample FIFO

Typical Applications

- Smart Mobile Devices
- Digital Cameras
- PCs



3x3mm QFN

MMA8451Q
14bit output, 99ug/rHz noise
High Pass Filter w/ DSP functions
Configurable Orientation detect
FIFO

MMA8452Q
12 bit output
High Pass Filter w/ DSP functions
Orientation detect

FXLS8471Q
14bit output, SPI
High Pass Filter w/ DSP functions
Configurable Orientation detect
FIFO

2x2mm DFN

MMA8652FC
12bit output, 160ug/rHz noise
High Pass Filter w/ DSP functions
Configurable Orientation detect
FIFO

MMA8653FC
10bit output
Orientation detect

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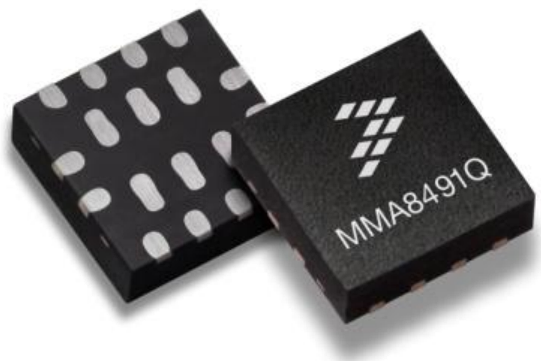
Xtrinsic MMA8491 (Plutino)

3-axis Extreme Low Power Digital Accelerometer

Differentiating Points

- Power Consumption (<0.35uA/Hz)
- Turn on time (<0.5ms)
- Ease of use (XYZ 45º tilt detect outputs)



Product Features

- 1.95V to 3.6V supply voltage
- ±8g range, 1mg/count sensitivity
- Sample rate from <1Hz to 800Hz+
- I²C digital output interface
- Enable pin for external power management
- 216µg/√Hz noise
- 3x3mm 0.65mm pitch w/ visual solder joint inspection

Typical Applications

- Remote Controls
- Smart Grid: Tamper Detect
- White Goods Tilt

Availability

- Limited Samples: NOW
- General Samples: NOW
- Volume Production: October 2012

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Xtrinsic MAG3110 (Maxwell)

3-Axis Magnetometer

Differentiating Points

- High accuracy compass function
- Decimator allows for lowest noise implementation with oversampling to remove RF noise and Idd induced mag fields

Product Features

- 1.95V to 3.6V supply voltage
- Maximum field of 10G (1000 uT)
- Output data rates (ODR) from 1.25Hz to 80Hz
- Magnetometer resolution of 0.1uT
- Current Consumption as low as 24uA at 1.25Hz
- I²C digital interface
- Extended temperature range of -40°C to +85°C.

Typical Applications

- Electronic Compass
- Enhanced User Interface
- Dead-reckoning GPS assist for Location Based Services

Package

2 x 2 x 0.85mm QFN

Availability

In Production
Online Sample Program
Buy Direct
Distribution Stocked

Xtrinsic FXOS8700CQ (Gauss)

6DOF (3-axis Accelerometer, 3-axis Magnetometer)

Differentiating Points

- Lowest noise gcell and mcell
- Embedded Functionality to allow system fast response and power savings
- 32 sample FIFO with burst read

Product Features

- 1.95V to 3.6V supply voltage, I/O 1.6V – 3.6V
- ±2g/±4g/±8g accelerometer, ±15 Gauss Field range
- Output data rate (ODR) from 1.563Hz to 800Hz , 400Hz hybrid
- 14-bit gcell data, 800 counts per Gauss
- Low Offset Drift: 0.1mG per deg
- 4 channel motion detect ion- FF, Pulse, Transient, HPF, Tap
- Vector Magnitude for mcell, gcell

Typical Applications

- Electronic Compass
- Enhanced User Interface
- Dead-reckoning GPS assist for Location Based Services

Package

3 x 3 x 1.2mm QFN

Availability

- Dev Tool orderable – Dec'12
- Production – Feb'13

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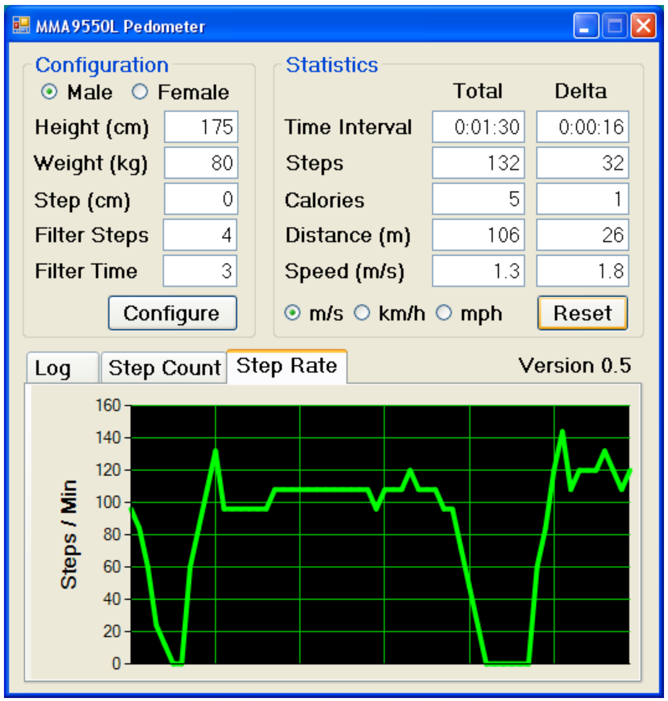
Xtrinsic Sensor Fusion and Enablement

Pedometer



FSL Embedded Solution

Configurable settings:

- Step length can be set manually or calculated from height & weight.
- Filter resists false step counts.

Flexible outputs:

- 99.9% step count accuracy.
- Calorie count
- Distance
- Average speed
- Lap counter holds recent results

Use case: Always ON.

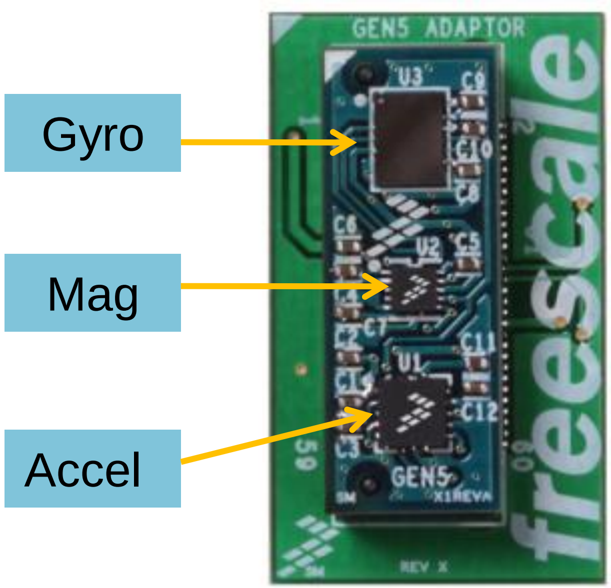
- Hiking, tourist, activity monitors
- No screen functionality generally needed.

Gesture Library (SW & HW)

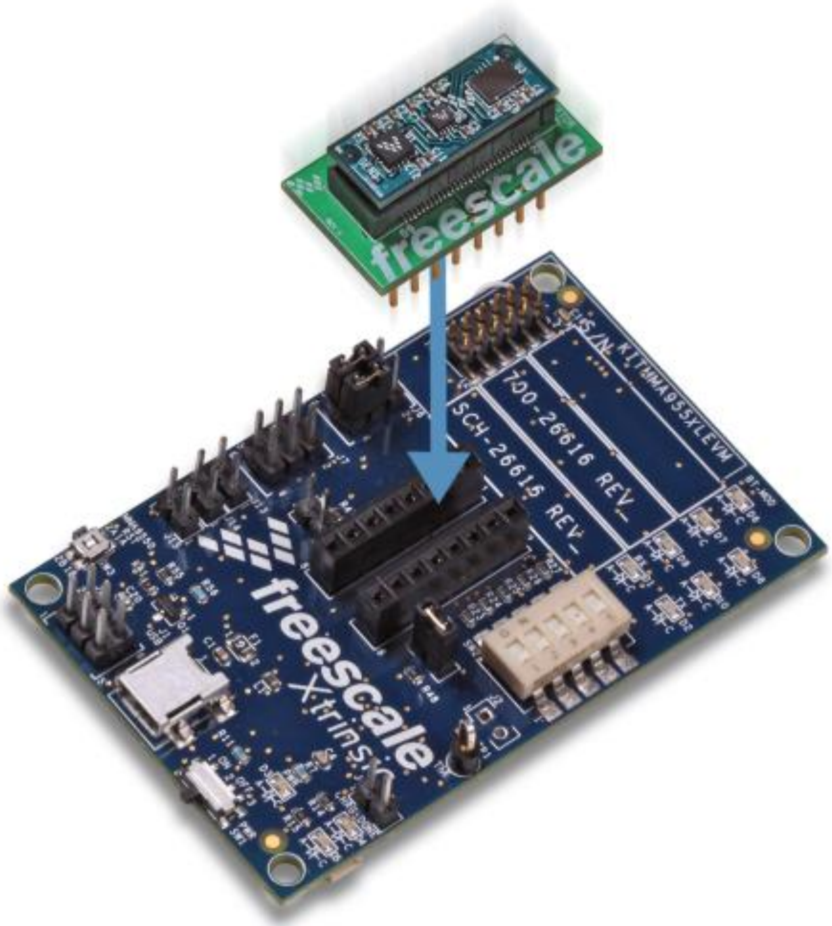
- Orientation detection
- Tilt measurement
- Tap and double tap detection
- High pass filters
- Automatic wake-up
- Automatic sleep
- Motion detection with threshold
- Free fall detection
- Transient detection
- Power saving modes
- Filtering
- …

9DOF Hardware Implementation for Data Collection and Algorithm Development

- Gen 5 supporting MSM8xxx
- 9 DOF ready
- Shorten time-to-market
- Allow specific pre-developments



21 mm x 7.6 mm 9DOF Board



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Miscellaneous Sensor Topics

Accelerometer Sample Code – Windows

```
var accelerometer;
accelerometer = Windows.Devices.Sensors.Accelerometer.getDefault();
accelerometer.addEventListener("readingchanged",onAccReadingChanged);

function onAccReadingChanged(e) {
    var accelX = e.reading.accelerationX;
    var accelY = e.reading.accelerationY;
    var accelZ = e.reading.accelerationZ;
}
```

Source: http://blogs.msdn.com/b/b8/archive/2012/01/24/supporting-sensors-in-windows-8.aspx

Accelerometer Sample Code – Android

```
public class SensorActivity extends Activity, implements SensorEventListener {
        private final SensorManager mSensorManager;
        private final Sensor mAccelerometer;

        public SensorActivity() {
           mSensorManager = (SensorManager)getSystemService(SENSOR_SERVICE);
           mAccelerometer = mSensorManager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
        }

        protected void onResume() {
           super.onResume();
           mSensorManager.registerListener(this, mAccelerometer, SensorManager.SENSOR_DELAY_NORMAL);
        }

        protected void onPause() {
           super.onPause();
           mSensorManager.unregisterListener(this);
        }

        public void onAccuracyChanged(Sensor sensor, int accuracy) {
        }

        public void onSensorChanged(SensorEvent event) {

                accelX = event.values[0];
                accelY = event.values[1];
                accelZ = event.values[2];
        }
    }
```

source: slightly modified from that found at http://developer.android.com/reference/android/hardware/SensorManager.html

Sensor Security

- Android restricts application access to user approved features via the application manifest. For instance, an application has to ask for permission to use GPS information when installed.
- Windows 8 has a similar function with its manifest. The application must declare its intention to use location, microphone, proximity, sms or the webcam.
- Neither restricts magnetic/inertial sensor use via these mechanisms. This presents a possible security gap.
- See Proof-of-concept Android Trojan uses motion sensor to determine tapped keys for more details.

Power Management

On Windows 8

- Sensors are powered down when the screen is off
- Sensors are powered up only when required by running applications
- These use standards eliminate the possibility of another VERY useful feature: using the accelerometer to wake the device

On Android

- “Always make sure to disable sensors you don't need, especially when your activity is paused. Failing to do so can drain the battery in just a few hours. Note that the system will *not* disable sensors automatically when the screen turns off. ” – http://developer.android.com/reference/android/hardware/SensorManager.html

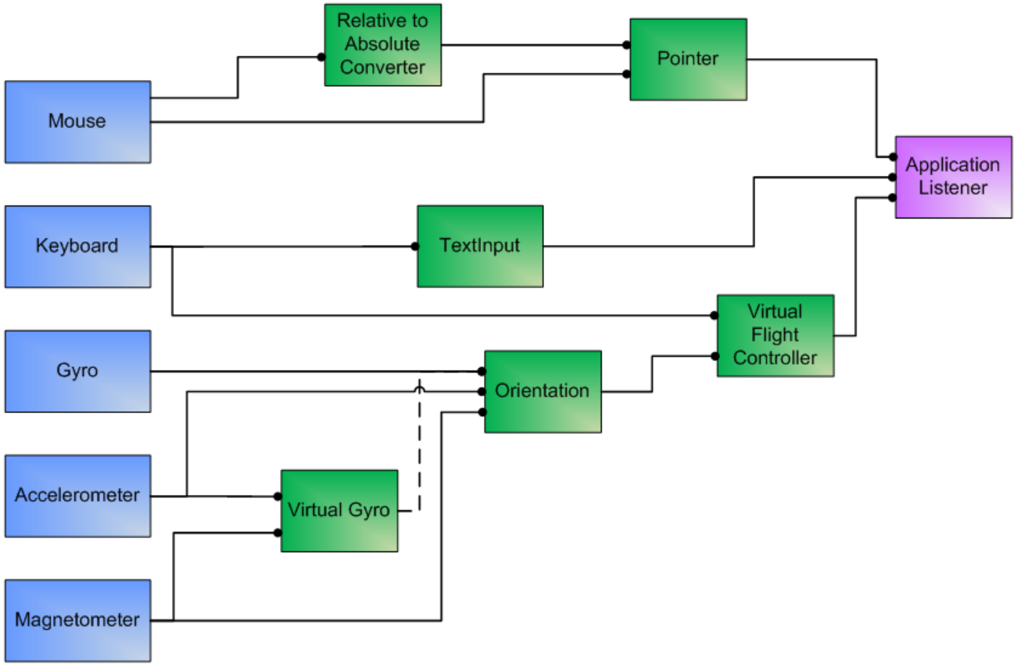
Additional Areas for Sensor Framework Enhancement

We still see a number of opportunities for enhancements in the sensor subsystem that could increase the capabilities and user value:

- Setting the sample rate and resolution when multiple applications are requesting data with different settings
- Identification of key gesture / motion signatures by the sensor subsystem rather than the applications processor
- Integration of altitude (pressure) into 3-D positioning
- Enabling the offload processor to run downloaded applications. Opens up a new market of sensor applications (pedometer, fall detection, drop detection)
- Integration with WiFi / GPS / cell tower positioning techniques to use sensors for short term dead reckoning

StreamInput

- StreamInput uses Semantic Interface definitions to abstract physical sensor types.
- Semantic interfaces can describe both physical and virtual sensor types.
- A graph structure is used to dynamically build a hierarchy of interface types.
- Sensor configurations can change on the fly.
- Designed to be easily extended and compatible with existing OS'es.



Freescale Collaborates with Khronos Group in Definition of StreamInput

- The Khronos StreamInput working group is driving industry consensus to create a cross-platform API to enable applications to discover and use new generation sensors to create sophisticated user interactions. The new API will support a general-purpose framework for consistently handling advanced sensors such as depth cameras, touch screens and motion and orientation sensors as well as traditional input devices.”

- Collaborators include: Freescale, Aptina Imaging, Sensor Platforms, SoftKinetic, ST Microelectronics, TransGaming, Texas Instruments, PrimeSense, Intel, Nvidia, Qualcomm, Samsung

- http://www.khronos.org/

- See “Creating an Industry Standard” by Gavriel State at http://www.gamasutra.com/blogs/GavrielState/20120502/169669/Creating_An_Industry_Standard.php

Wrap Up

We have covered:

- Software / sensor fusion overview
- Snapshot: Android and Windows today
- Xtrinisic support for Android
- Xtrinsic support for Windows 8
- Freescale involvement in the Khronos StreamInput effort

References

- http://www.freescale.com/sensordrivers
- W3C “Device Orientation Event Specification” at http://dev.w3.org/geo/api/spec-source-orientation.html
- Integrating Motion and Orientation Sensors with PC Hardware Running Windows 8, Version 0.7, September 13, 2011, Microsoft Corporation
- The HID Class Driver for Sensors, September 13, 2011, Microsoft Corporation
- TSSMCU: Xtrinsic Touch Sensing for Microcontrollers

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